91602
new 82-10

LEGAL NOTICE

This report was prepared by Ontario Hydro and, while effort has been made to assure the accuracy and applicability of the material contained herein, neither Ontario Hydro nor any person acting on its behalf:

(a) makes any warranty, express or implied with respect to the use of any information, apparatus, method or process disclosed in this report or that such use may not infringe privately owned rights; or

(b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method or process disclosed in this report.

ontario hydro
research division

COMPLIMENTARY COPY
Please Credit Ontario Hydro Research if Reproduced in Whole or in Part

WESLEYVILLE POOL-FIRE TEST FACILITY

Report No 90-85-K

D. Taralis / G. Morandin
Engineer / Technologist
Applied Mechanics Section
Mechanical Research Department

ABSTRACT

An open-pool fire test facility has been designed and built at the Wesleyville TGS site for the fire testing of spent-fuel shipping containers as well as other types of package requiring fire testing. A large fire test pan of 4.5m outer diameter is protected from the wind by a cylindrical perforated metal sheet screen 14m in diameter and approximately 6m in height. Fuel supply to the pan is gravity-fed through 3 elevated drums at 2.5m above ground. Monitoring of the fire test is accomplished with a data acquisition system capable of handling up to 400 input signals from thermocouples and pressure transducers. Several kerosene fire tests have confirmed the adequacy of the facility to produce fully engulfing fires with flame temperatures in excess of 800 °C. Future plans include the promotion of the facility to test other types of container.

job	file	date	report no.
21-316-401	825.122	May 2, 1990	90-85-K

91602
new 82-10

91-00812/

ontario hydro
research division

EXECUTIVE SUMMARY

WESLEYVILLE POOL-FIRE TEST FACILITY

D. Taralis / G. Morandin
Engineer / Technologist
Applied Mechanics Section
Mechanical Research Department

A large-pool fire test facility has been errected at the Wesleyville TGS site for testing the survivability of spent-fuel shipping containers to hypothetical fire accident environments. Of immediate need was the use of the facility to conduct fire tests on two Concrete Integrated Container (CIC) scaled models. Several kerosene fires performed so far revealed the following:

1. Perforated metal screens used for reducing wind disturbances on the flame appear very effective while allowing continuous flow of air to the combustion process.

2. Fully engulfing flames with temperatures in excess of 800 °C (minimum limit set by AECB) are readily accomplished.

3. Temperature and pressure measurements can be conveniently made by the ORION data logger and a COMPAQ computer. High scanning rates allow fluctuations in flame temperatures to be measured and processed to produce time averages for use during the test.

Burning kerosene or any other liquid fuel can be handled with the present pan arrangement. Modification of the existing fuel pan to handle gaseous fuels is planned in the immediate future.

DC.
JC

job	file	date	report no.
21-316-401	825.122	May 2, 1990	90-85-K

TABLE OF CONTENTS

1.0 INTRODUCTION	1
2.0 SITE SELECTION AND REQUEST FOR APPROVAL	1
2.1 Site Selection	1
2.2 Request for Approval	2
3.0 TESTING AND DESIGN AND CONSTRUCTION	2
3.1 Laboratory Testing	2
3.2 Design and Construction	3
4.0 INSTRUMENTATION AND DATA ACQUISITION	4
4.1 Instrumentation	5
4.2 Data Acquisition	5
5.0 OPERATION OF FACILITY	6
5.1 Kerosene Fuel	6
5.2 Other Types of Fuel	6
6.0 FUTURE PLANS	7
7.0 CONCLUSIONS AND RECOMMENDATIONS	7
ACKNOWLEDGEMENTS	8
REFERENCES	9
APPENDIX A	10
APPROVAL OF OPERATION	
FIGURES 1 to 20	15 - 39
DISTRIBUTION	last page

LIST OF FIGURES

1. Road Map to Wesleyville Pool Fire Test Facility
2. View of Wesleyville Site
3. Details of Wind Screen
4. Schematic Diagram of Fire Test Facility
5. View of Fire Test Facility
6. Fuel Pan
7. Wind Screen Post Assembly
8. Model Stand
9. Fuel Supply Tower
10. Data Acquisition System
11. Control Room
12. Premiere of the Facility
13. Concrete Blocks Before Fire Test
14. Fire Engulfing Concrete Blocks
15. Concrete Blocks at End of Fire Test
16. Preheating of Quarter-Scale CIC Model
17. Quarter-Scale CIC Model Before Fire Test
18. Pickering Fireman Igniting Fuel Pan
19. Initial Stages of Flame Development
20. Intermediate Stages of Flame Development
21. Final Stages of Flame Development
22. Fully Developed Flames
23. View of Facility in Operation
24. Quarter-Scale CIC Model at End of Fire Test
25. Measurements of Flame Temperatures

ontario hydro
research division

To Dr. D. Mills
Director of Research

WESLEYVILLE POOL-FIRE TEST FACILITY

1.0 INTRODUCTION

Before nuclear waste containers can be used for transportation, their survivability during a postulated fire accident scenario must be demonstrated to regulatory authorities. Past experience with external fire test facilities /1,2/ revealed that to meet Ontario Hydro's fire test requirements (flame temperature, fire duration, flame size, etc) and time schedule, an in-house fire test facility was needed. The main objectives for constructing the fire test facility were:

a) To be able to test various types of small as well as large packages.

b) To have the flexibility to burn many types of liquid/gaseous fuel for extended test durations.

This report describes the history of events from the site selection, small-scale testing, the full scale design and the construction of the facility. It further describes the kerosene fires performed to date and makes recommendations for extending the versatility of the facility.

2.0 SITE SELECTION AND REQUEST FOR APPROVAL

2.1 Site Selection

In selecting a site for the fire test facility the following criteria were considered:

a) To find a location that will be approved by management

b) To obtain approval from the Ministry of Environment to operate the facility

c) To be at a convenient distance so that the total time required to carry out a given test should be within one day.

On the basis of the above requirements three different locations (Bruce NPD, Middle Port TS and Wesleyville TGS) were considered. The site at Wesleyville was found most suitable and was, therefore selected. Figure 1 shows the way to the facility and Figure 2 is a view of the Wesleyville site.

2.2 Request for Approval

Before proceeding with the construction of the fire test facility it was necessary to obtain approval for operation from the Ministry of Environment in Peterborough. To ensure that approval would be granted the number of fire tests were limited to two with maximum duration of 15 minutes each. These tests were for the Concrete Integrated Container (CIC). The request for approval is presented in Appendix A.

The response from the Ministry of Environment was positive. The approval stipulates that kerosene fire tests can be conducted at the Wesleyville site provided that the Ministry is notified 48 hours in advance and the winds are blowing from the land to the lake. The letter of approval is also included in Appendix A.

3.0 TESTING AND DESIGN AND CONSTRUCTION

This section describes the laboratory experience gained from small-scale tests and the extrapolation to full-scale design and construction of the facility.

3.1 Laboratory Testing

The purpose of the experimental fire testing was to gain an appreciation of the important parameters governing pool fires burning kerosene/heptane. In this exploratory study the following parameters were investigated:

a) Type of wind screens

b) Size of wind screen enclosure

c) Size of fire pan

d) Level of flame temperatures

A number of wind screens were used (fine wire mesh, perforated metal sheet and solid metal/nylon sheet) in the experimental tests. The best screen seemed to be the perforated metal screen (see Figure 3). It has the property of deflecting the wind in a certain direction (depending on the orientation of the perforations) while significantly reducing wind disturbances on the flame cover. The non-perforated metal screen performed very poorly in terms of keeping the flame centered. It always pulled the flame to the wall of the screen which led to a non-engulfing fire. The dimensions of the wind screens (diameter and height) as well as the fuel pan size were also investigated to understand the effects of these parameters on the dynamics of the combustion process. A diameter to height ratio of 2.5 was found adequate. The kerosene flame temperatures were compared with heptane flame temperatures and found to be about the same (both above 800 °C). Kerosene, however, produces a much darker black cloud of smoke than heptane.

3.2 Design and Construction

The knowledge gained from the small-scale laboratory fire tests was used to design and construct the full-scale fire test facility at the Wesleyville site. The dimensions of the model were scaled up by a factor of approximately 20. A schematic diagram of the facility is shown in Figure 4 (see also Figure 5). The diameter of the space enclosed by the screen is 14 meters and its height is about 6m. The main components of the facility are briefly described below:

Fuel Pan. The complete pan consists of an inner pan 3m in diameter and an outer pan 4.5m in diameter (see Figure 6). For smaller models (up to 1m long) the inner pan can provide a fully engulfing fire while for larger containers (up to 2.5m long) the outer pan should be used. In case of the remote possibility of a leaking pan the entire double fuel pan is contained within a 5m diameter pan.

Wind Screens. The details of the post attachment to the ground is shown in Figure 7. It consists of a concrete block burried in the ground with 4 steel bolts protruding from the top surface of the block. A steel pipe (88.9mm Sch 40, 6m high) is screwed to the concrete block. The entire 14m circular space has 12 posts equally spaced on its perimeter. The perforated steel screens were assembled into 12 panels before attaching them to the posts. Each panel was mounted between two posts by

attaching the horizontal flat bars of the panel to the posts through the use of sliding rings. One of the 12 panels was used as an entrance to the facility by mounting one of its sides to the post using hinges while leaving the other free. To provide extra strength to the structure in case of extremely high winds, guy-wires were used to connect the top of each post to the ground radially outwards.

Model Stand. The model support was designed and built with the intention of being used for different container sizes. The support frame consists of two identical components. Each component is of fixed width and consists of two vertical columns filled with concrete and welded together with two horizontal members (see Figure 8). Both parts of the stand were wrapped with fire resisting blanket to protect them from the fire. Depending on the length of the container to be tested, the two stand components can be moved closer or further apart as required. The height of the support frame is such that the bottom surface of the container will be 1 meter above the fuel level.

Fuel Supply. The fuel supply to the pan is gravity-fed through a 50.8mm line from 3 elevated drums supported horizontally at a height of 2.5m (see Figure 9). It is released below the water surface in a well-distributed pattern. The fuel floats to the surface of the water where it is burned. A number of concrete blocks are placed within the pan to minimize wave formation and fuel spattering during burning. Next to the valve used for admitting fuel, there is a fuel level indicator showing the fuel level in the pan. The level indicator is connected to the fuel pan through a 12.7mm piping system. The fuel drums are approximately 30m away from the screens of the facility.

To simulate the initial conditions of the container under normal operation strip heaters are used to preheat the container to the desired temperature level. Up to 14 strip heaters can be mounted around the outer surface of the container. To reduce heat loss to the ambient air during preheating the model is wrapped with fiberfrax blanket. The heaters provide approximately 2 Kw from 120 VAC power supply which is adequate for this application.

4.0 INSTRUMENTATION AND DATA ACQUISITION

This section briefly describes the instrumentation and data acquisition system of the facility.

4.1 Instrumentation

The basic instrumentation consists of thermocouples (T/Cs) and pressure transducers (PTs). The thermocouples are used to measure the flame temperature and the temperature of the package at various locations. Since flame and model temperatures are in the range of 0 to 1000 °C, 1/16" type K T/Cs are used. Each thermocouple consists of a lead wire approximately 20m long and an inconnel sheath section of 7.6m long for the fire environment. Two strain gauge type pressure transducers in the range of 0 to 200 (KPa)g are used to measure the pressure inside the container cavity. The use of heat flux meters to measure the total heat flux (by convection and radiation) is presently under consideration.

4.2 Data Acquisition System

The T/Cs and PTs described above are connected to a data logging unit. The data logger known as the ORION delta has the capacity of handling up to 600 analogue inputs. The present capability of this system consists of 20 input modules with 20 channels per module giving a total of 400 input channels. The system can scan up to 150 channels/second and the data can be stored on magnetic tape and printed out on its thermal printer. The data can also be sent to other devices through its two RS-232C serial ports. Presently a portable COMPAQ computer is connected to the data logger through one of its serial ports. It has a 20 MB hard disk and one disk drive (362 KB). The data from the ORION data logger can be further processed by the computer using BASIC and then stored on the hard disk for later use. A printer can also be atached to the COMPAQ computer through its parallel port for plotting any results shown on the computer screen. Figure 10 shows the COMPAQ computer and the ORION data logger. During the fire test the data acquisition system uses the flame temperatures to perform the following calculations:

a) Instantaneous and time average of the flame temperatures

b) Test duration based on scaling laws/3/

c) Elapsed time from the start of the test

d) Remaining time before the fire goes out

A portable office (see Figure 11) approximately 20m away from the entrance of the facility is used to protect the data acquisition system from the weather. The office has a square base (2.44m x 2.44m) and is 2.74m high. The main features of this office include 2 fluorescent light fixtures, one exhaust

fan, one baseboard heater(500 W) and and two 110V receptacles. The office has three windows (1.22m x 0.91m) and is insulated with R12/R20 fibreglass insulation.

5.0 OPERATION OF FACILITY

So far the facility has been used with kerosene fuel which produces heavy, dense, black clouds of smoke. Other types of liquid fuels such as heptane can also be used with the present fire pan configuration.

5.1 Kerosene Fuel

The current experience with the facility involves burning kerosene fuel. Ignition of kerosene is facilitated by spraying a thin layer of gasoline on top of the kerosene fuel. A fully engulfing flame is usually accomplished within 60 seconds after ignition. Figures 12 to 24 show pictures of the various fires performed so far (no object, concrete blocks and 1/4 scale CIC model). The results of the 1/4 CIC fire tests will be presented in a future report/4/. The flame temperatures measured at a number of locations within the flame are shown in Figure 25 and it can be seen that the flame temperatures fluctuate with time and also vary with position within the fire. All temperatures are above the minimum limit of 800 °C set by AECB regulations.

5.2 Other Types of Fuel

The existing fuel pan arrangement is suitable for burning other types of liquid fuel. It is also possible to use solid fuels, although this is not of importance here. Of current importance, however, is the burning of gaseous fuels such as propane gas or natural gas. The combustion of gaseous fuels is basically smoke-free and is, therefore, preferred from an environmental standpoint. However, before propane fires can be used as a means of determining the survivability of irradiated fuel transportation containers, their equivalence to kerosene fires must be assessed.

The modification of the existing fuel pan arrangement to handle propane gas (or any other type of gas) is quite straight forward. It involves the construction of several concentric rings to distribute the gas evenly within the pan and a bed of sand/gravel placed over the rings. A large propane tank, which is commercially available, can be used to supply propane gas to the pan through a 101.6mm pipe line about 50m long. For safety reasons the tank might have to be placed underground. The plan is to incorporate this aspect of design into the facility in the

immediate future.

6.0 FUTURE PLANS

A number of activities have been planned in the near future. These include:

a) Making improvements to the facility for a more automated operation and for increasing the versatility of the existing fire pan to burn gaseous fuels such as propane gas or natural gas.

b) Carrying out one fire test on the 1/2 scale CIC model using kerosene.

c) Promoting the use of the facility within as well as outside Ontario Hydro to test other types of package subjected to a fire environment.

It should be noted that any improvements made to the facility will be of a short duration and should, therefore, not affect any fire test schedule.

7.0 CONCLUSIONS AND RECOMMENDATIONS

a) Approval for conducting fire tests at the Wesleyville Fire Test Facility has been obtained from the Ministry of Environment.

b) Several kerosene fires, carried out recently, demonstrate the unique capability of the facility for testing spent-fuel shipping containers.

c) Perforated metal sheet screens prevent the flame from being blown away from the container while allowing the required air flow for combustion. They also serve as a shield to protect surrounding equipment.

d) The facility is capable of producing flame temperatures in excess of 800 °C which is the minimum limit set by AECB regulations.

e) Visual observation of the test package and fire is through the perforated wind screening which provides almost 100% visibility making it ideal for photography and video camera.

f) Existing data acquisition capabilities include 400 analogue inputs from T/Cs and PTs. High scanning speeds (up to 150 channels/s) can be achieved allowing rapidly varying signals (flame temperatures) to be sampled many times per second.

g) Presently the existing fuel pan can be used with liquid fuels such as kerosene or heptane. It is recommended that its versatility be extended in the immediate future so that gaseous fuels (propane/natural gas) can be burned.

h) Originally the facility was built for the fire testing of nuclear waste containers. However, other types of various package sizes can also be tested.

ACKNOWLEDGEMENTS

Messrs S. Losee and S. Kanellos from Wesleyville TGS Site as well as all who helped in the construction of the facility are greatly acknowledged.

Approved by:

G.J. Clarke
Manager
Mechanical Research Dept

Submitted by:

D. Taralis
Engineer
Stress Analysis & Heat Transfer
Applied Mechanics Section

G. Morandin
Technologist
Stress Analysis & Heat Transfer
Applied Mechanics Section

Reviewed by:

T.P Byrne
Unit Head
Stress Analysis & Heat Transfer
Applied Mechanics Section

REFERENCES

1. Taralis, D. and Morandin, G., "Fire Testing of Half-Scale Road Cask for 10 Year Cooled Irradiated Fuel, Ontario Hydro Research Division Report No. 88-127-K, May 17, 1988.

2. Smith, S. M., "Effects of High Temperature on Restrained Concrete - CIC Fire Test at ULC", IFTU Memorandum No. 201 (Rev 0), March 15, 1989.

3. Taralis, D. and Morandin, G., "Plan to Conduct a Fire Test on a Concrete Integrated Container 1/4 Scale Model", IFTU Memorandum No. 196, Revision 0, April 24, 1989.

4. Taralis, D. and Morandin, G., "Fire Testing of 1/4 Scale CIC Model", Ontario Hydro Research Division Memorandum to S.M. Smith, Nuclear Engineering Dept., January 23, 1990.

APPENDIX

APPROVAL OF OPERATION

This Appendix presents the request for approval to operate the fire test facility and the approval received from the Ministry of Environment in Peterborough.

Mr. P. Roussel
Senior Environmental Officer
Ontario Ministry of Environment
139 George St N
PETERBOROUGH, Ontario
K9J 3G6

May 11, 1989

File 825.122(P)

Approval Requested for Conducting Fire Tests on Simulated Transportation Containers of Spent Fuel at Wesleyville TGS

Dear Mr. Roussel:

Further to our telephone conversation of May 10,1989 I am providing the following information related to the fire testing of the above containers:

1. The geographic location of the experimental set-up is shown in Figure 1. Approximate dimensions are shown in Figure 4. The fire tests are intended to be carried out 2 or 3 times a year.

2. At present we have an urgent requirement to conduct one fire test in August,1989. A second test is planned for March,1990.

3. The duration of each fire test will be about 15 minutes.

4. Similar fire tests have been carried out at Underwriters Laboratory of Canada, Scarborough, Ontario (J. Roberts 757-3611).

5. Ontario Hydro contact at Wesleyville TGS is Stan Losee (885-2515)

Additional information is attached (see page 3). To meet our tight schedule we must start getting ready now (we need at least 2 months preparation). We would appreciate it very much if we could get your approval to proceed as soon as possible.

Please let me know if you require further details.

Sincerely,

D. Taralis

D. Taralis
Engineer
Applied Mechanics Section
Mechanical Research Department

Additional Information

1. The type of fuel that will be used will be either kerosene or heptane. Kerosene produces black smoke which is basically opaque. Heptane produces a similar type of smoke except its colour is grey. The smoke plume of each fuel travels approximately 100 feet high and 1/2 Km horizontally, depending on wind conditions, before the smoke becomes diluted.

2. The fuel will be supplied from 3 elevated barrels of 200 litres each. A splash shield will be installed around the barrels to deflect any leak downward into a funnel type set-up (see Figure 9). This funnel will drain immediately into an adjacent sump filled with crushed rock. The volume of the funnel and sump will be equal to the largest fuel tank (200 litres).

3. The fire test pan will contain approximately 2000 litres of water with a layer of kerosene/heptane fuel of about 350 litres. A fire proof absorbing fibre (much larger than the pan diameter) will be placed under the pan. This will absorb any fuel spatter during the fire test.

4. The test model will be placed on supports centered within the test pan at an approximate height of 1 meter above the fuel surface. The pan will be filled with water and approximately a 5 cm layer of fuel on top. The fuel level will be controlled during the test by opening/closing the fuel supply system valve. When the desired test duration is reached the valve will be closed and the remaining fuel in the pan will be allowed to burn off. Regulatory agencies (Ontario Ministry of Environment) and appropriate Ontario Hydro staff (Wesleyville resident supervisor and security staff, Central Region) will get advanced notification of any fire testing.

5. In the event of a spill from any of the 3 fuel supply barrels the fuel supply valve to the test pan will be shut off as well as the individual valves of each of the barrels. The fuel leaking from the damaged barrel will be collected in the sump.

Ministry of the Environment
Ministère de l'Environnement
Ontario

Central Region
Région du Centre

138 George Street North
Peterborough Ontario
K9J 3G6
705/743-2972

139, rue George nord
Peterborough (Ontario)
K9J 3G6
705/743-2972

May 30, 1989

Mr. D. Taralis
Engineer
Applied Mechanics Section
Mechanical Research Department
Ontario Hydro
Research Division
800 Kipling Avenue
Toronto, Ontario
M8Z 5S4

Dear Sir:

RE: Fire tests on Transportation Containers
at Wesleyville TGS

Reference is made to your letter of May 11, 1989 and our subsequent telephone conversation on May 29, 1989.

It is our understanding that this proposal is for two, fifteen minute fire tests of transportation containers scheduled for August 1989 and March 1990 and the fuel to be used is either kerosene or heptane. Precautions are noted in the fuel storage and burning area for any fuel spillage. Smoke from the burn is not expected to be noticeable at the property line.

We have no objection to this proposal provided that the following conditions are met:

1. Our office is to be advised fourty eight hours in advance of the actual time and date of the burn.

2. The burn should take place on a day when the winds are blowing out from the land to the lake.

3. Ontario Hydro are required to report any complaints received as a result of the August/89 test to our office with the name, address and telephone number of the complainant.

Should the test in August 1989 be found to create unacceptable conditions, the March 1990 test will not be approved until adequate notifications have been made.

Please contact myself or Mr. R. Palliser of our staff in regards to this project.

Yours truly,

Bruce Hancock
Senior Environmental Officer
Abatement East Section

90-85

BWH:kh

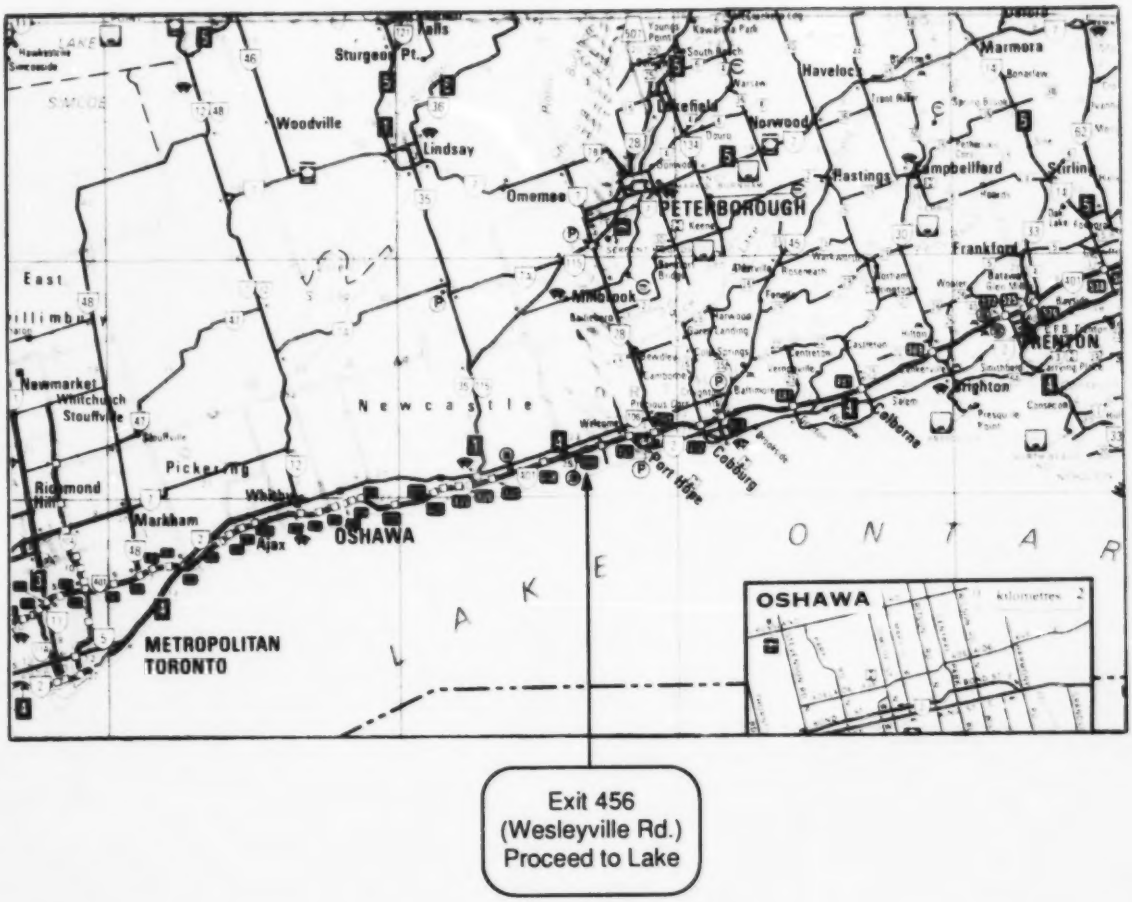


FIGURE 1

ROAD MAP TO WESLEYVILLE POOL FIRE TEST FACILITY

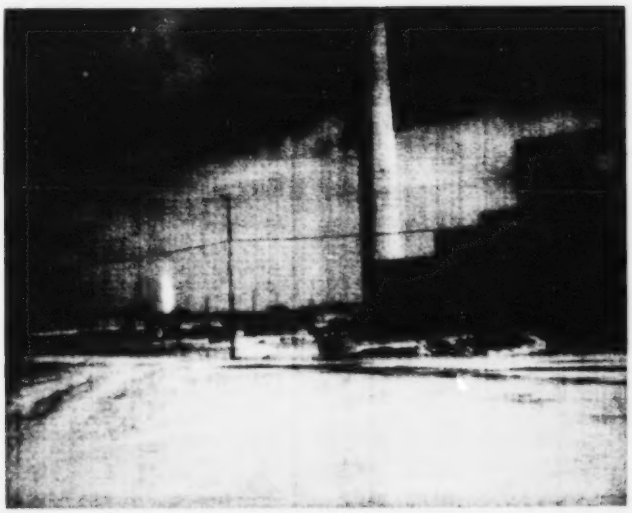


FIGURE 2

VIEW OF WESLEYVILLE SITE

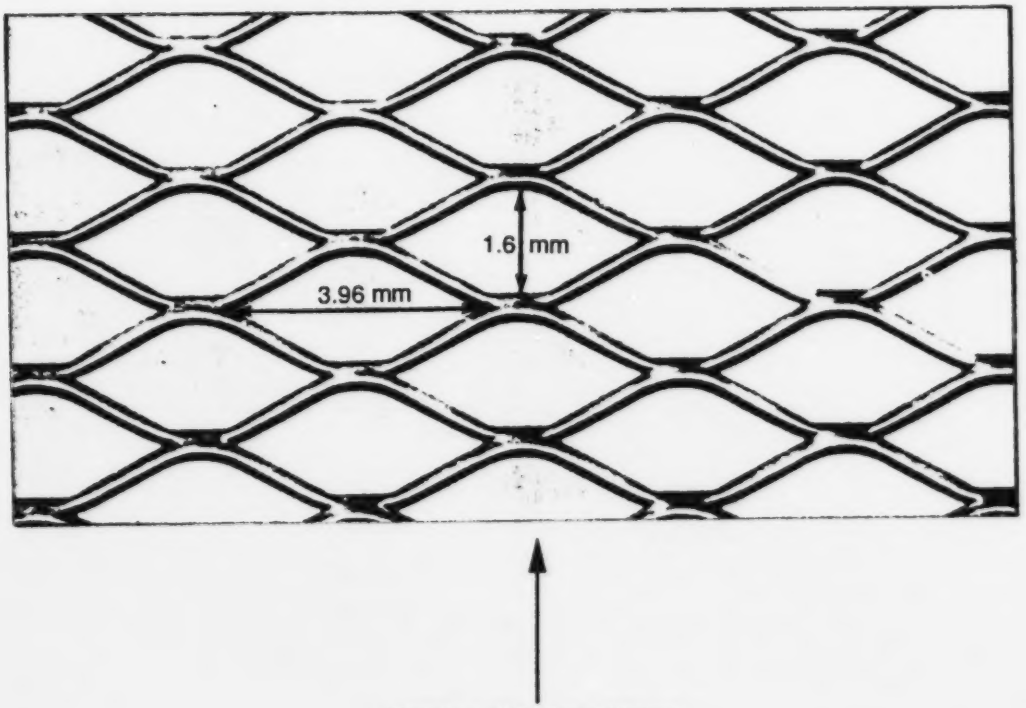


FIGURE 3

DETAILS OF WIND SCREEN

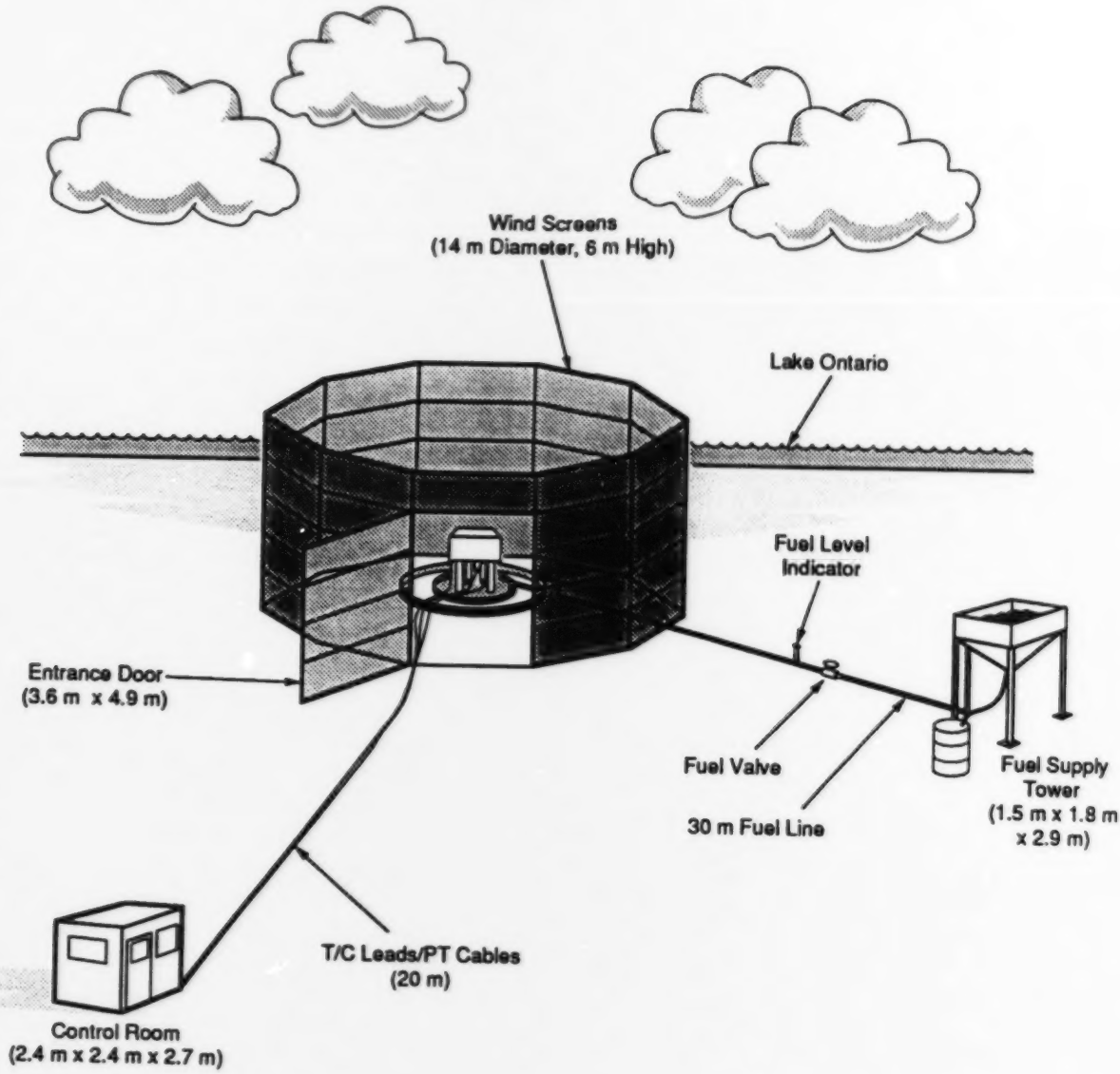


FIGURE 4

SCHEMATIC DIAGRAM OF FIRE TEST FACILITY

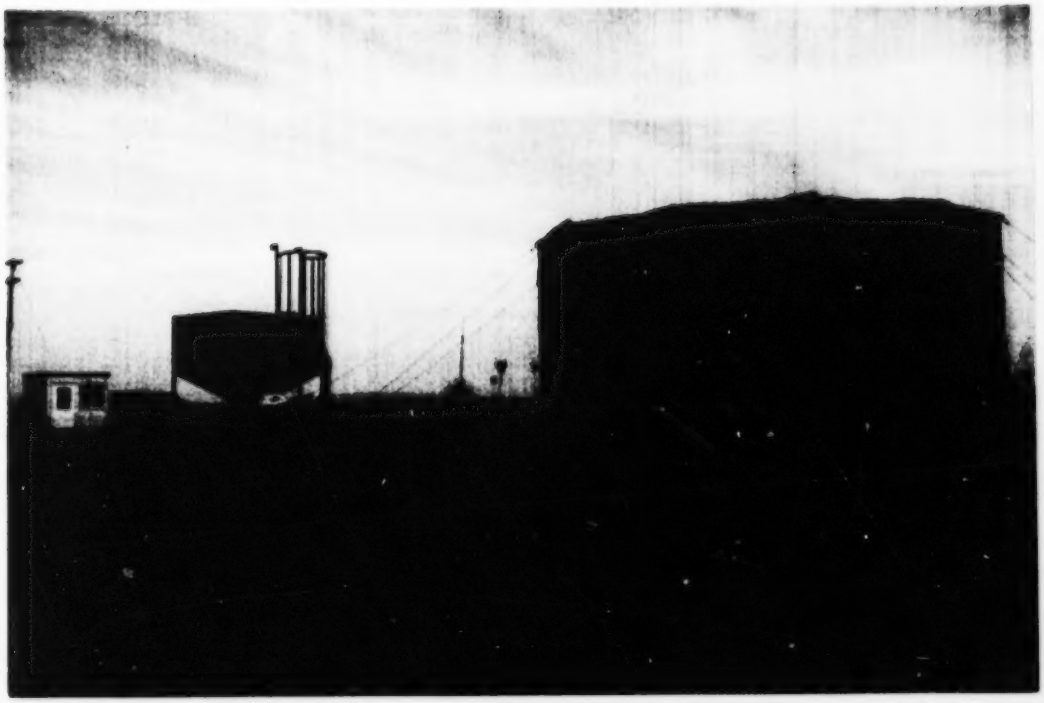


FIGURE 5

VIEW OF FIRE TEST FACILITY

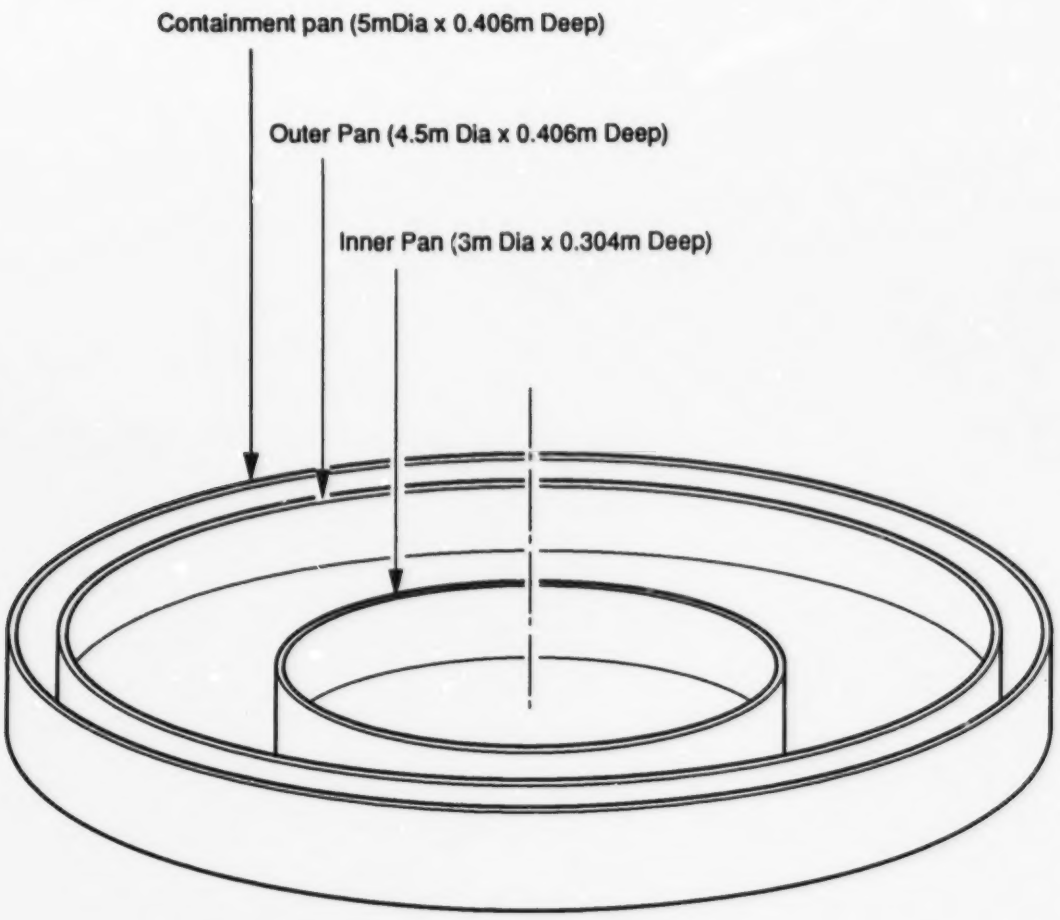


FIGURE 6

FUEL PAN

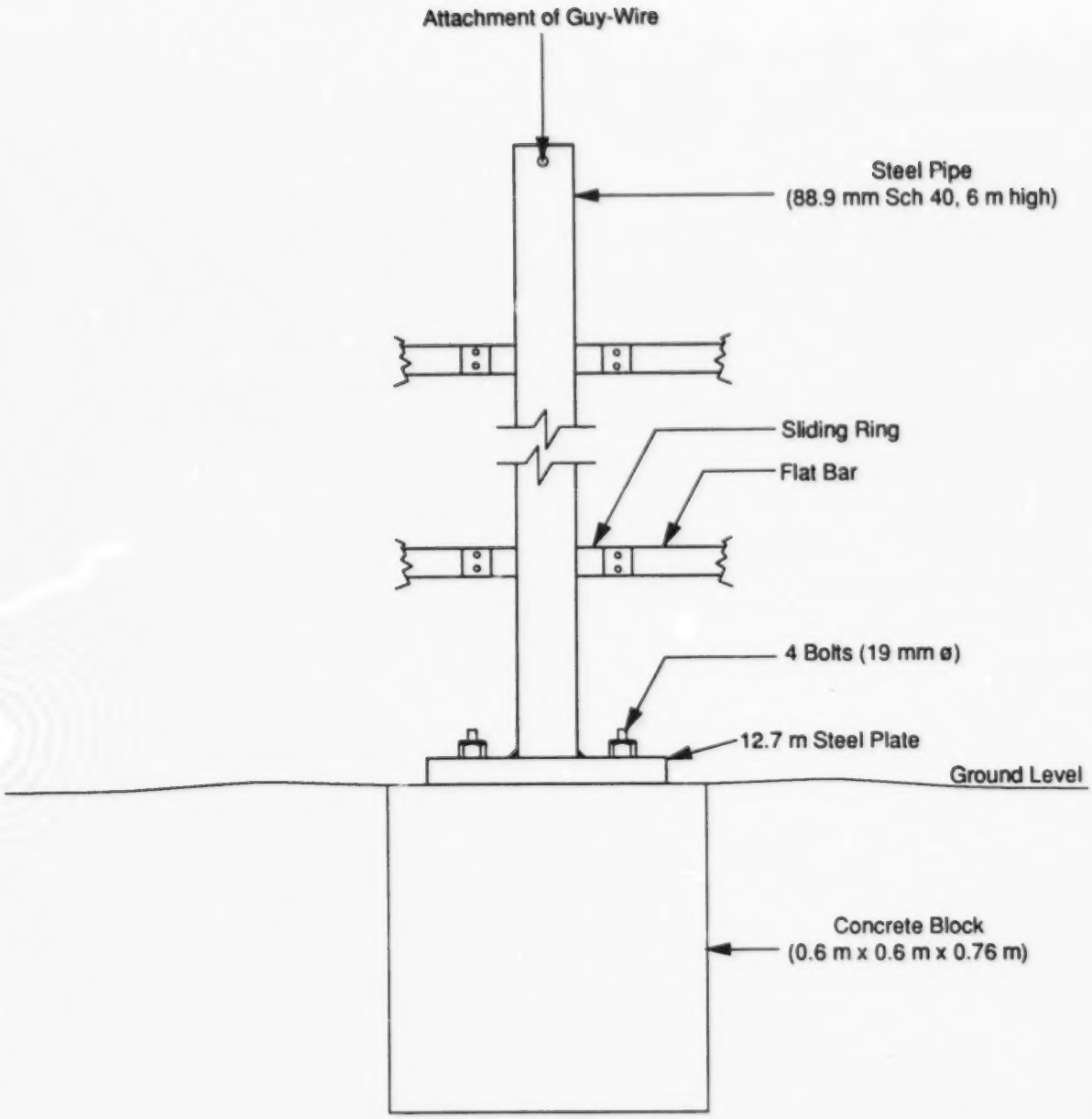
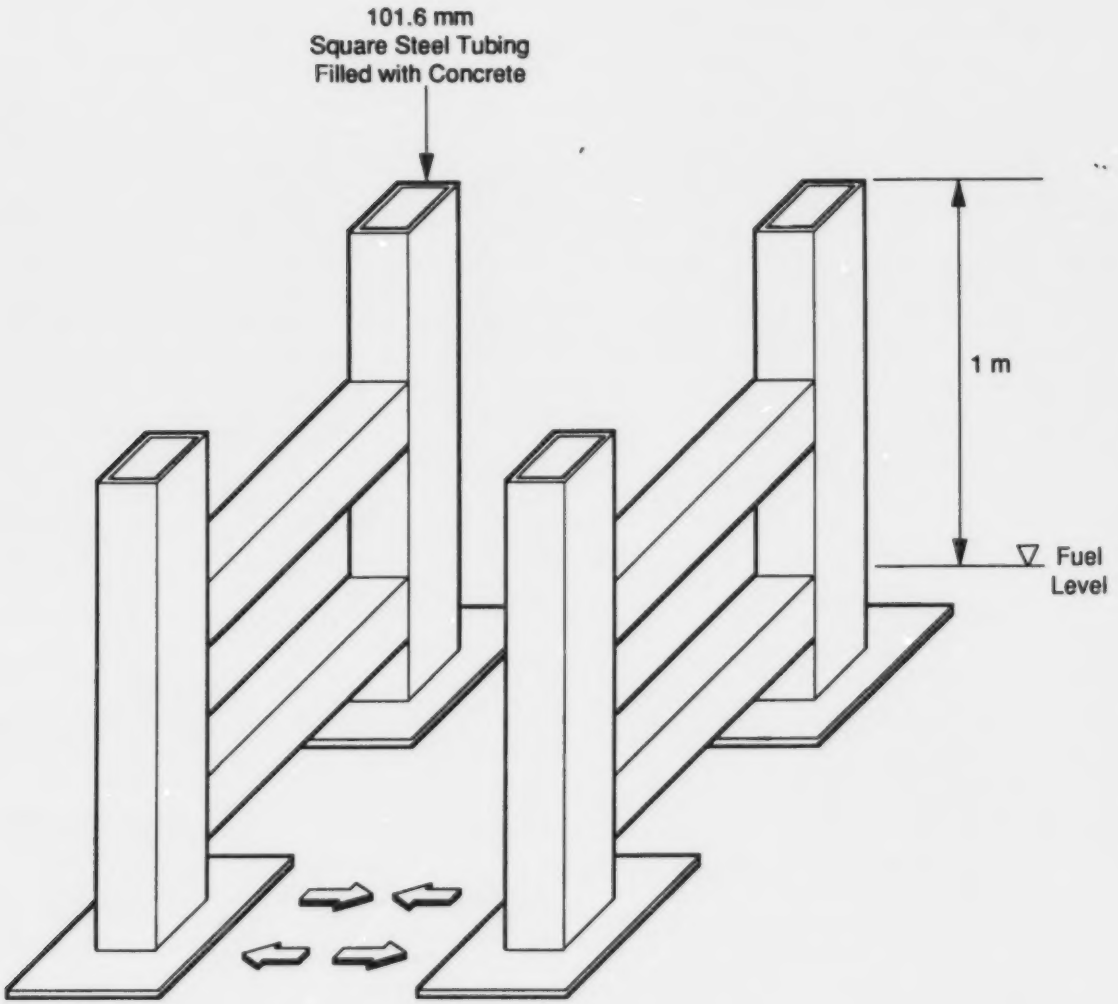


FIGURE 7

WIND SCREEN POST ASSEMBLY



- All Members Wrapped with Fire Resisting Blanket
- Can Move Closer/Further Apart

FIGURE 8

MODEL STAND

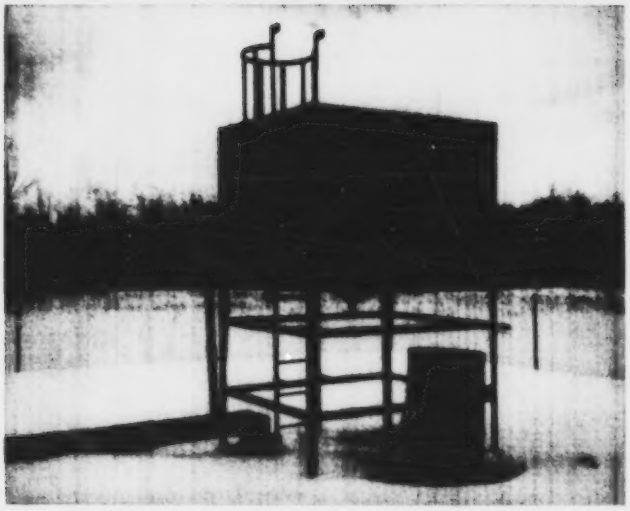


FIGURE 9

FUEL SUPPLY TOWER

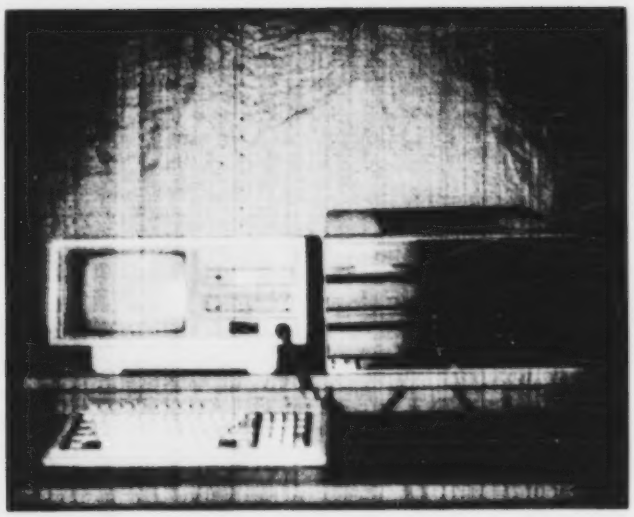


FIGURE 10

DATA ACQUISITION SYSTEM

FIGURE 11

CONTROL ROOM

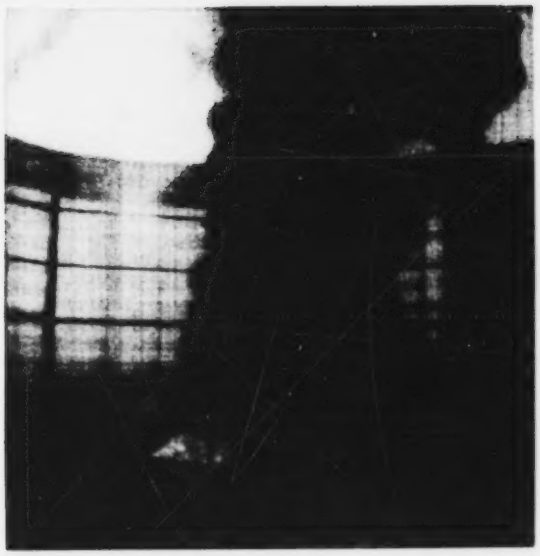


FIGURE 12

PREMIERE OF THE FACILITY

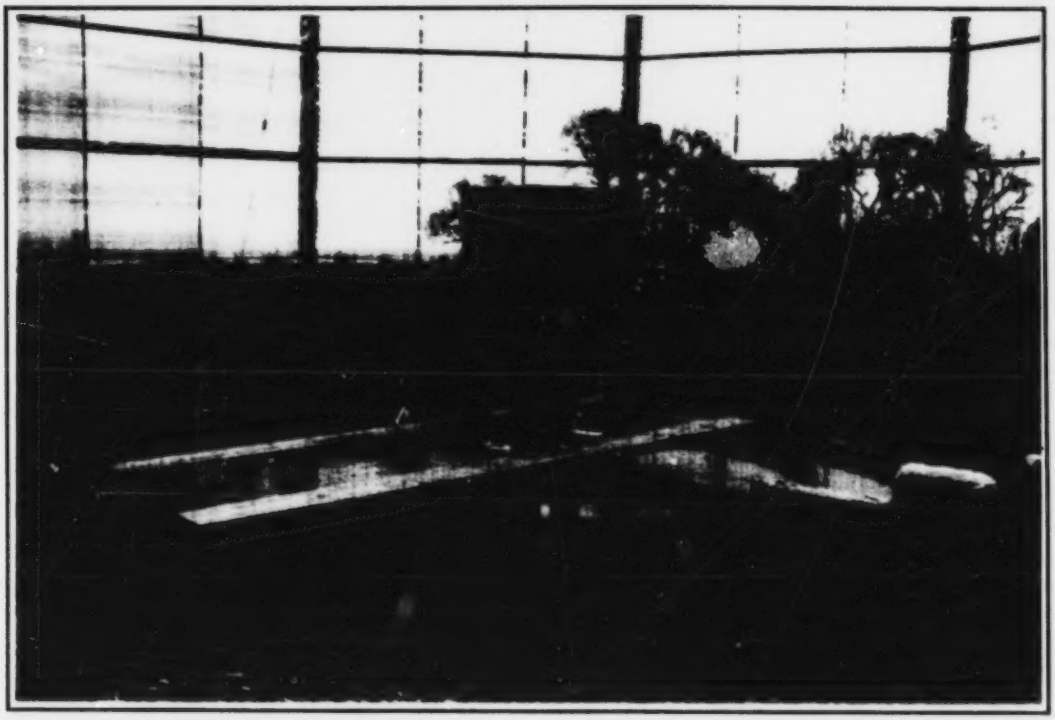


FIGURE 13

CONCRETE BLOCKS BEFORE FIRE TEST

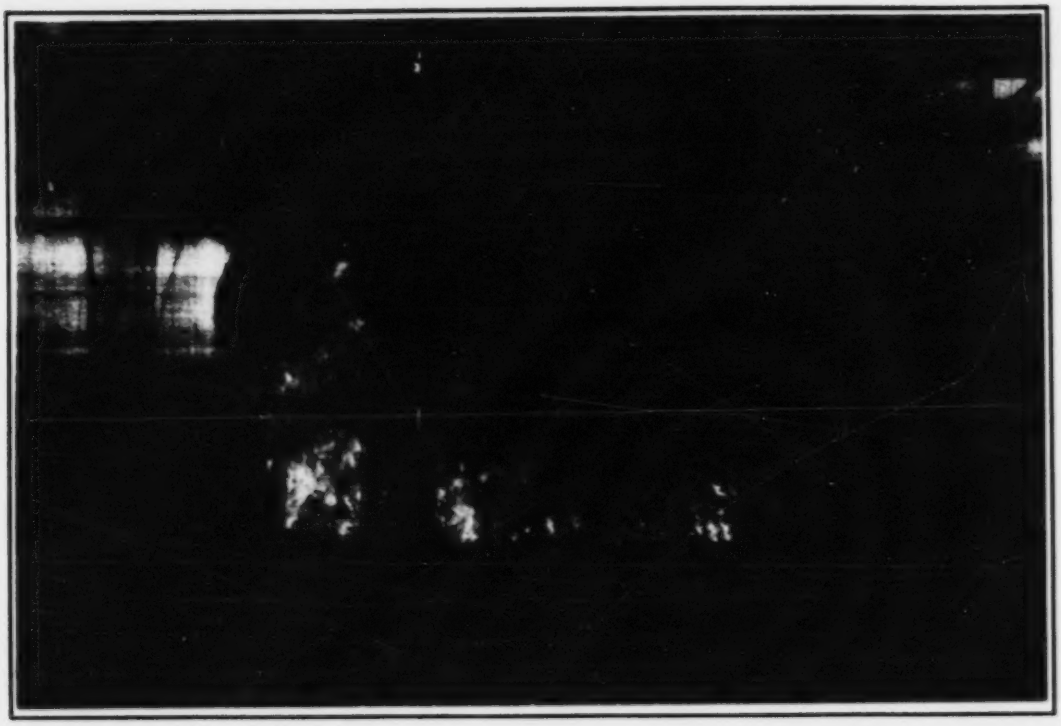


FIGURE 14

FIRE ENGULFING CONCRETE BLOCKS

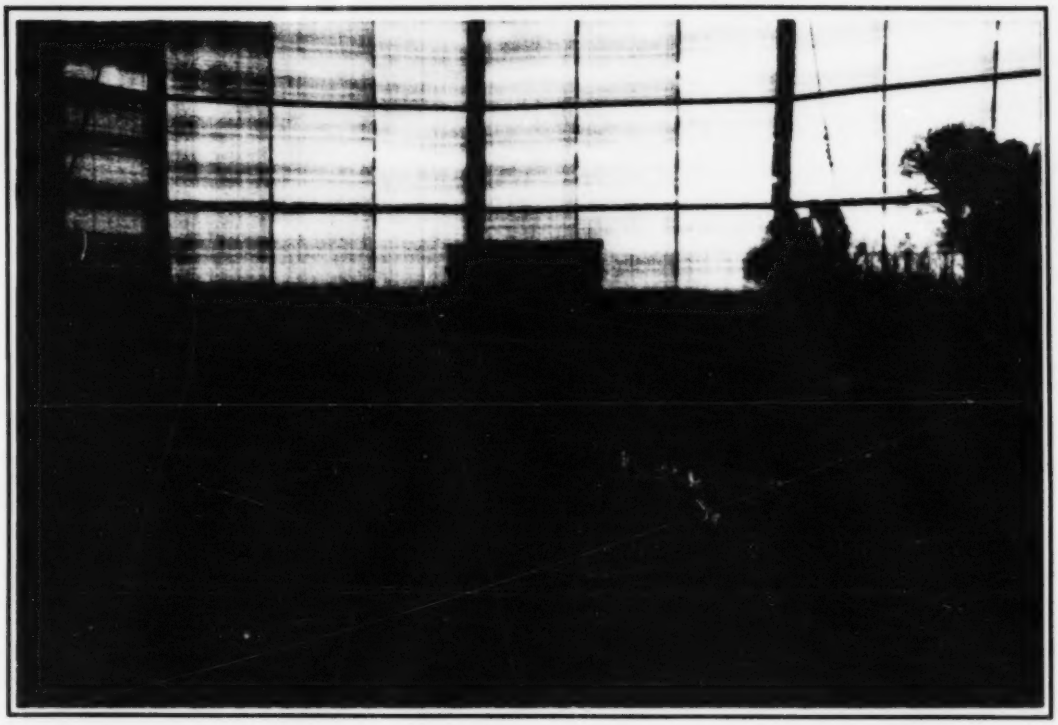


FIGURE 15

CONCRETE BLOCKS AT END OF FIRE TEST

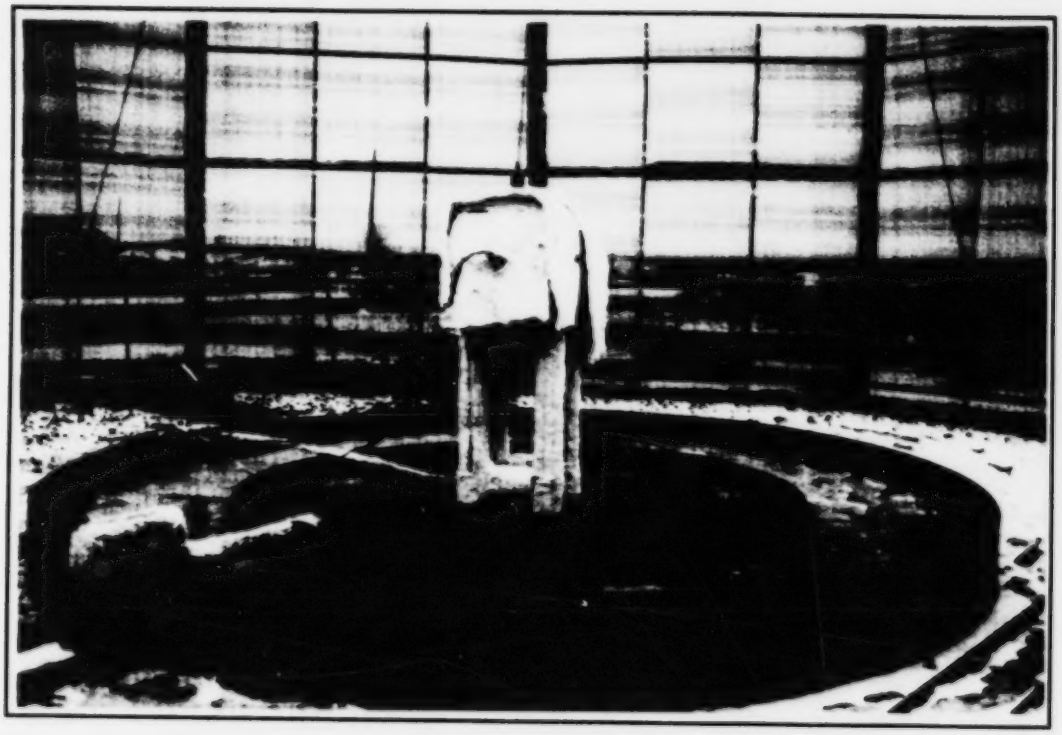


FIGURE 16

PREHEATING OF QUARTER-SCALE CIC MODEL

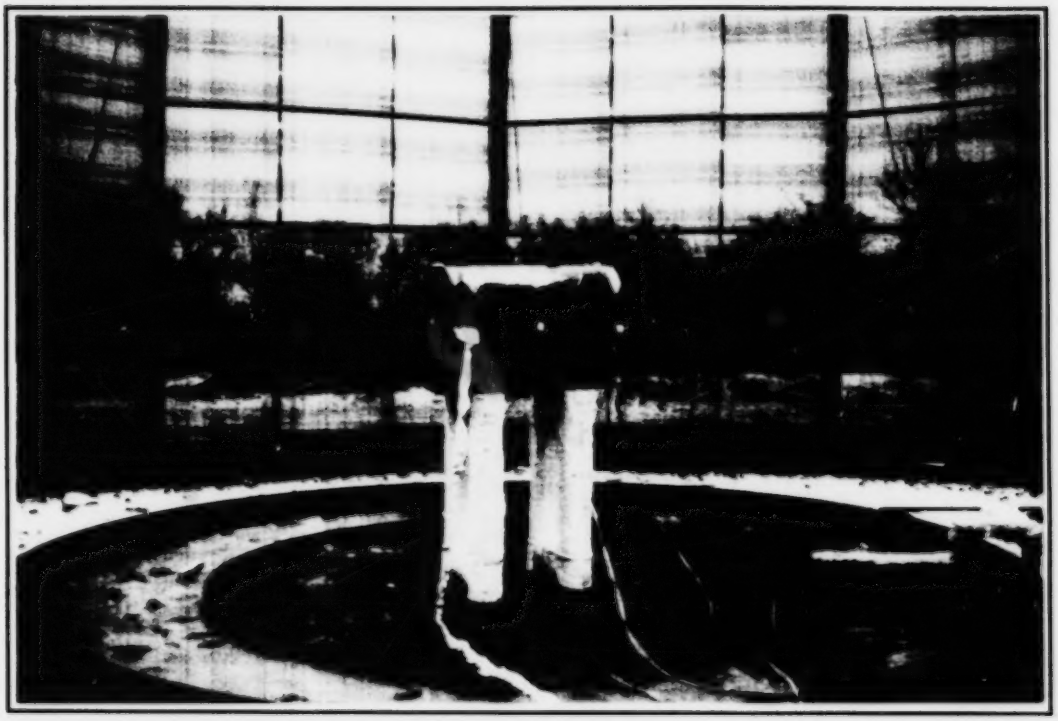


FIGURE 17

QUARTER-SCALE CIC MODEL BEFORE FIRE TEST

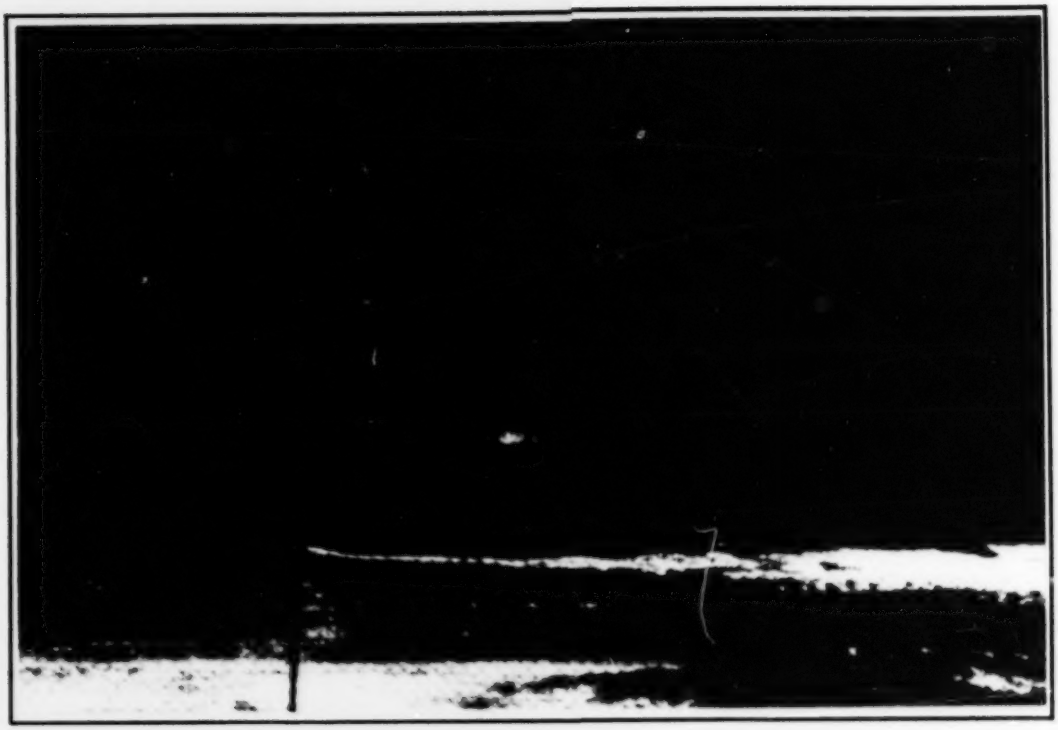
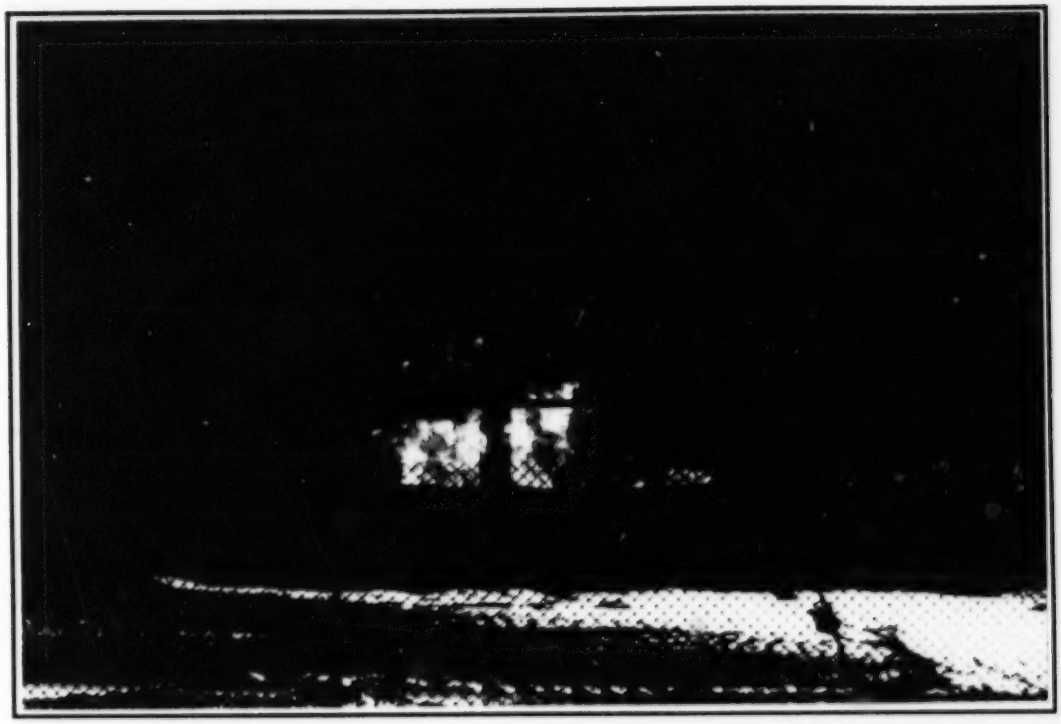


FIGURE 18

PICKERING FIREMAN IGNITING FUEL PAN



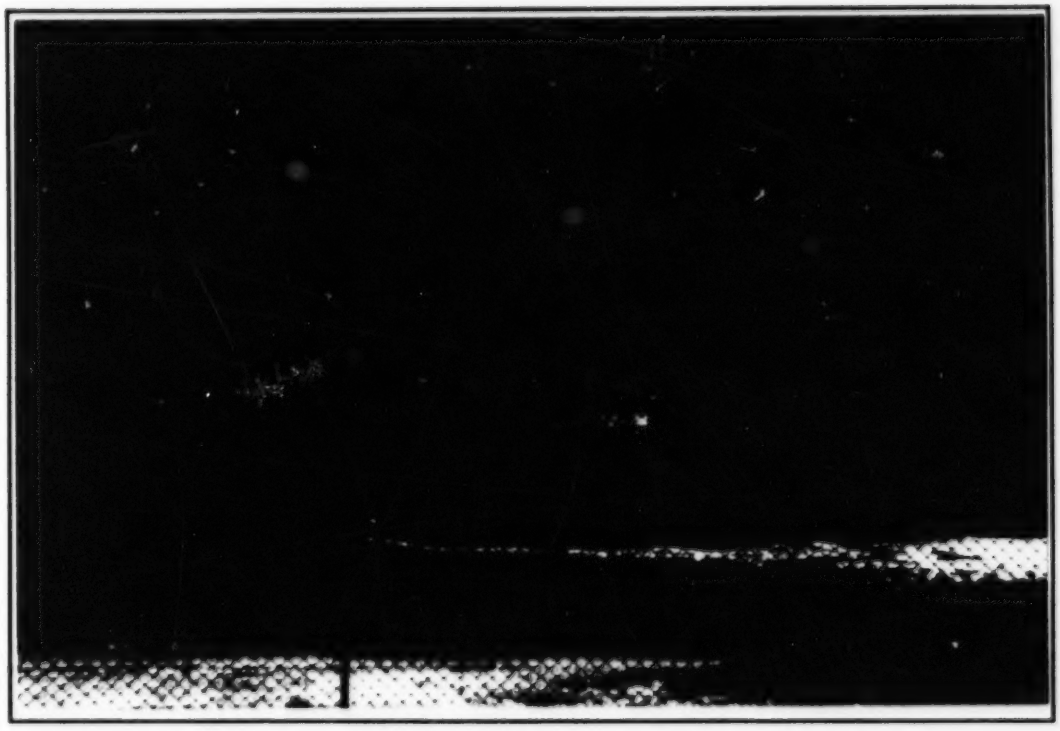
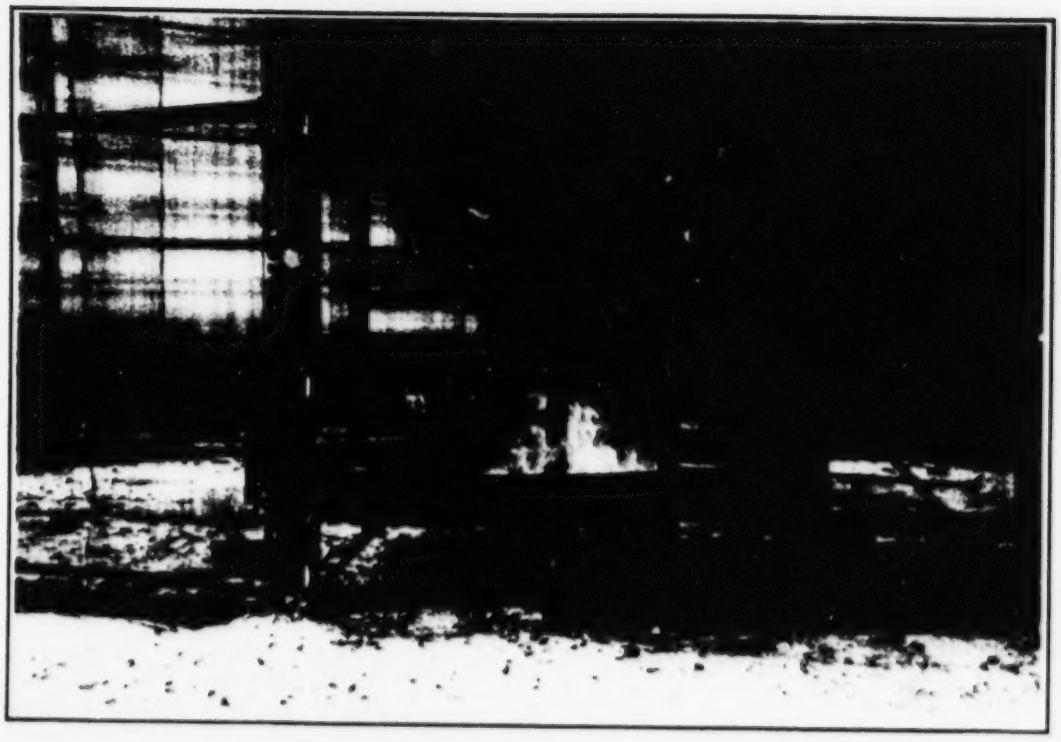


FIGURE 19

INITIAL STAGES OF FLAME DEVELOPMENT



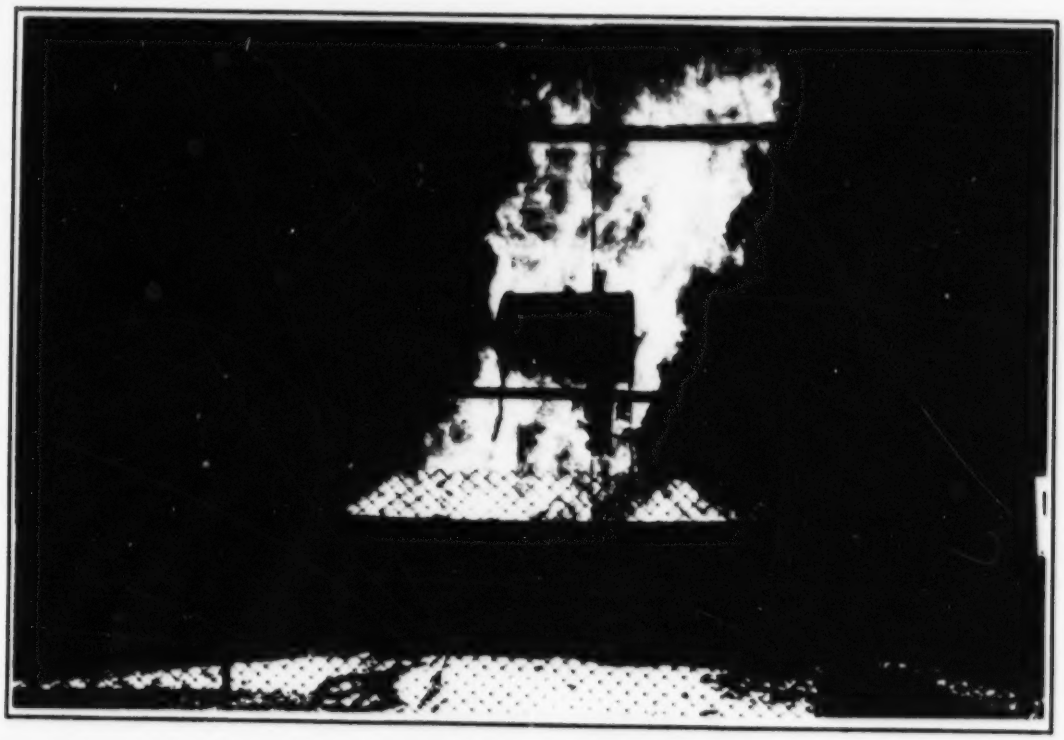


FIGURE 20

INTERMEDIATE STAGES OF FLAME DEVELOPMENT

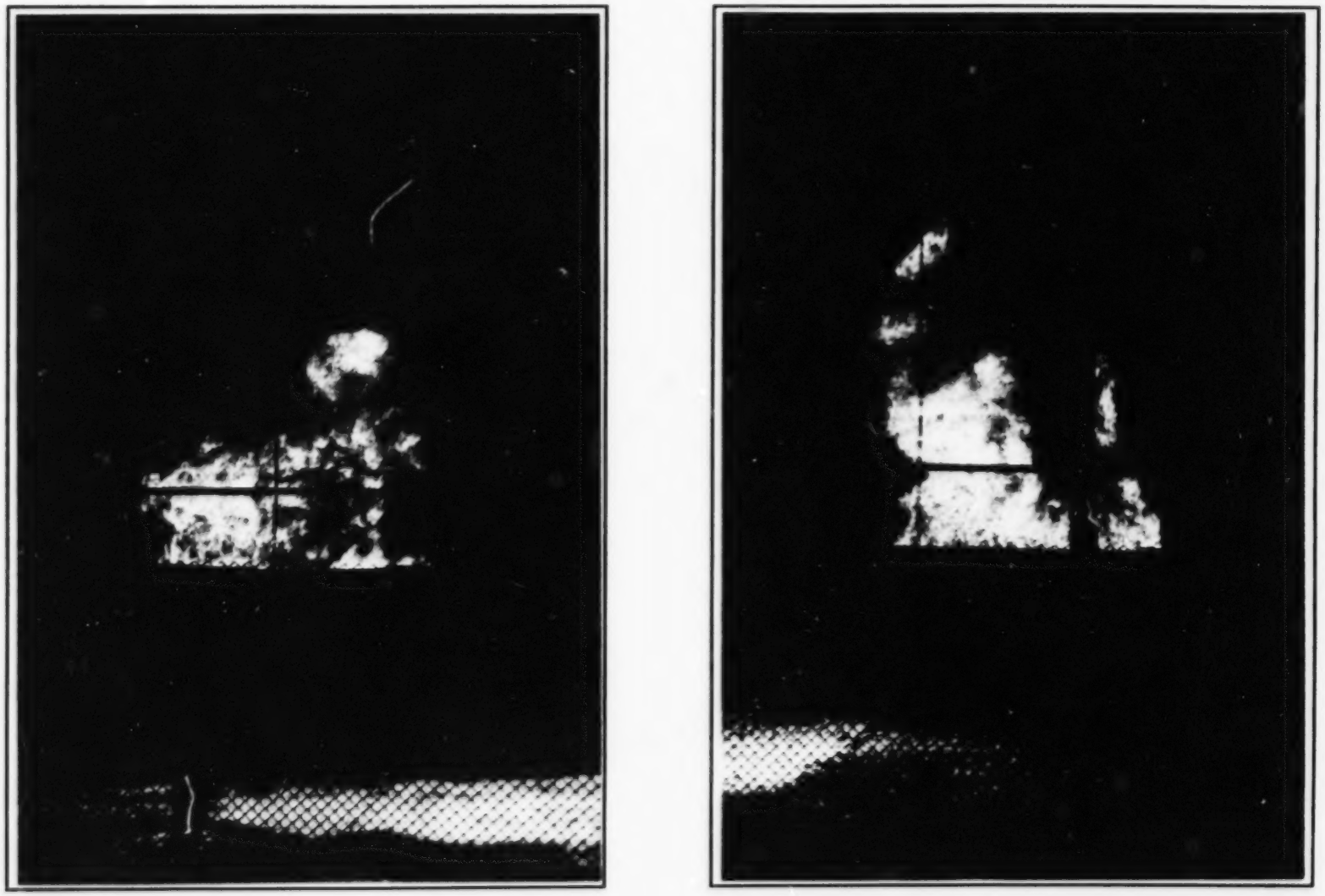


FIGURE 21

FINAL STAGES OF FLAME DEVELOPMENT

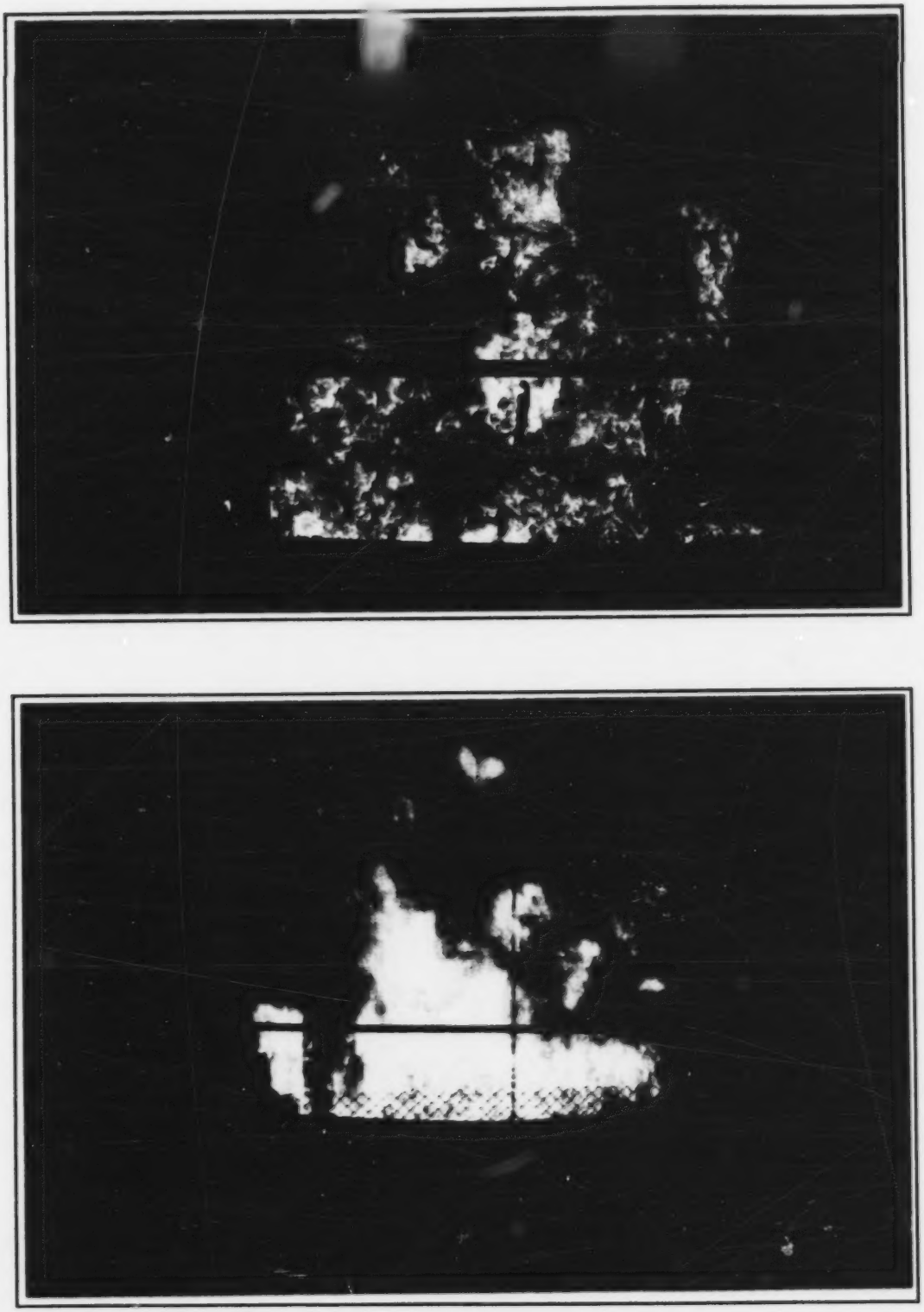


FIGURE 22

FULLY DEVELOPED FLAMES

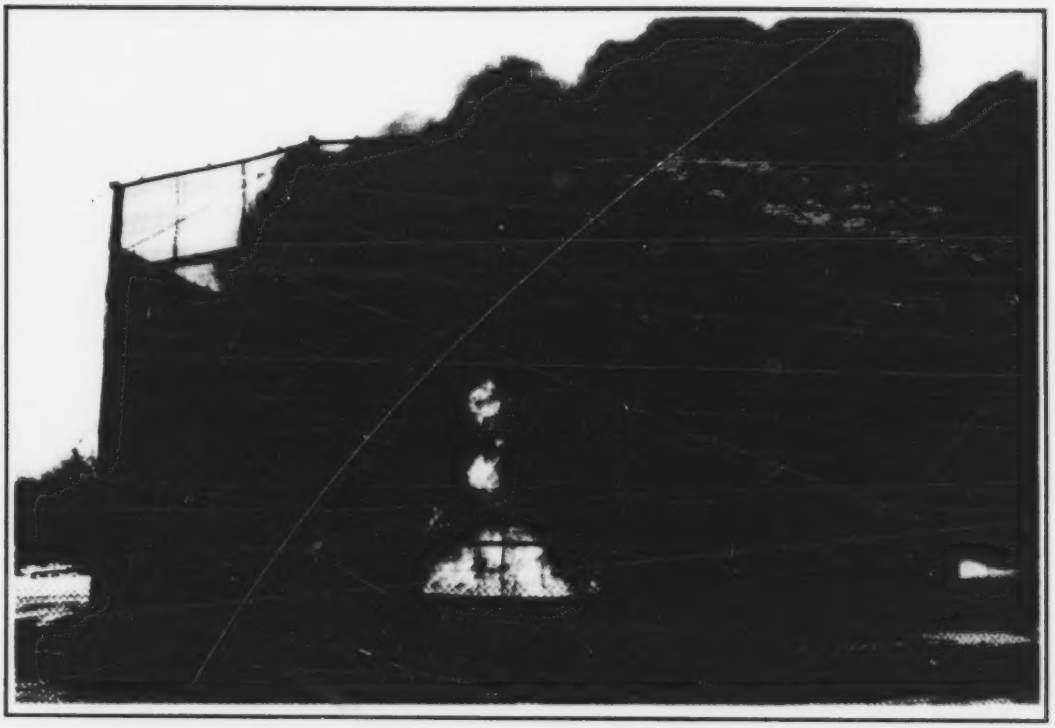


FIGURE 23

VIEW OF FACILITY IN OPERATION

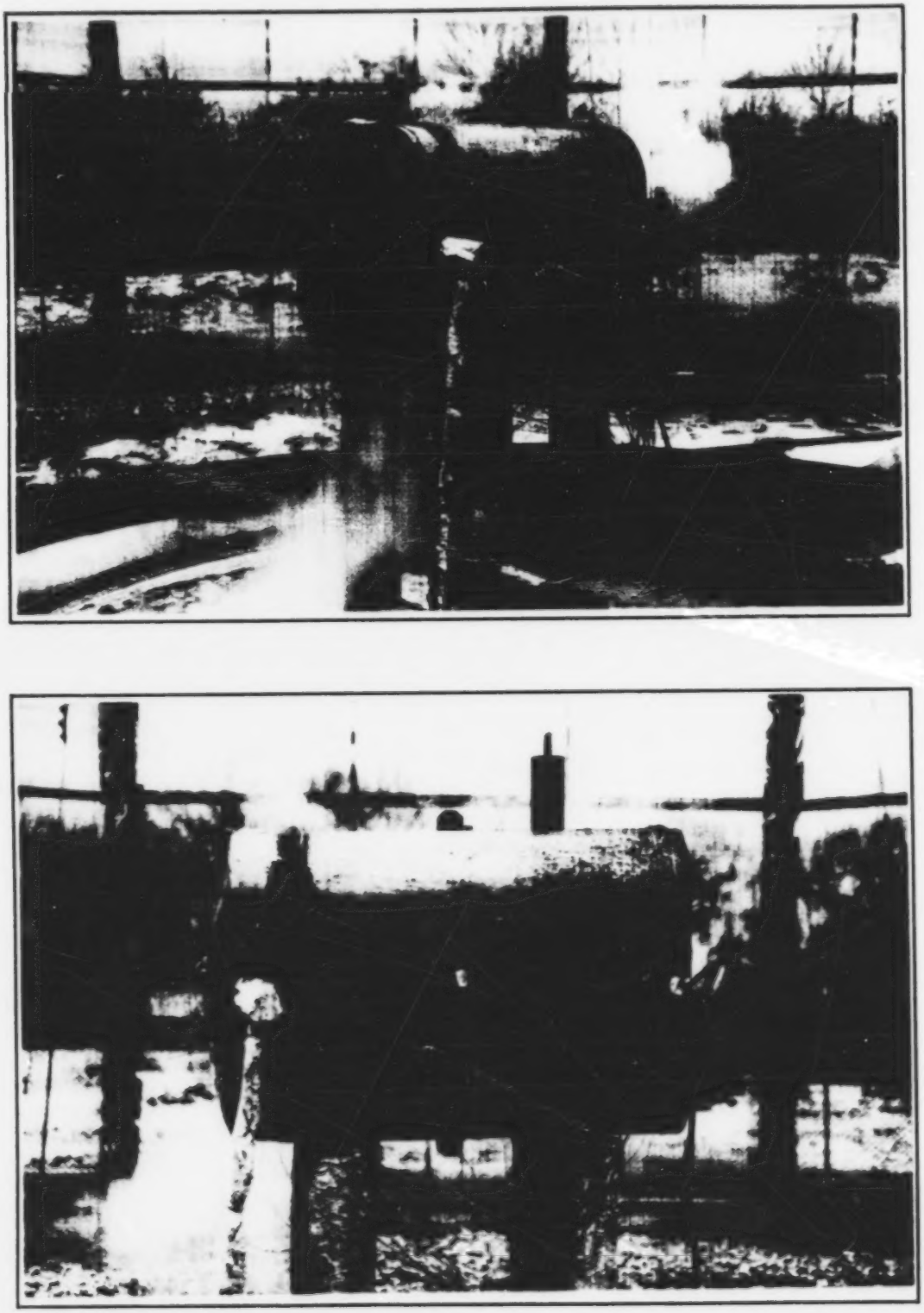


FIGURE 24

QUARTER-SCALE CIC MODEL AT END OF FIRE TEST

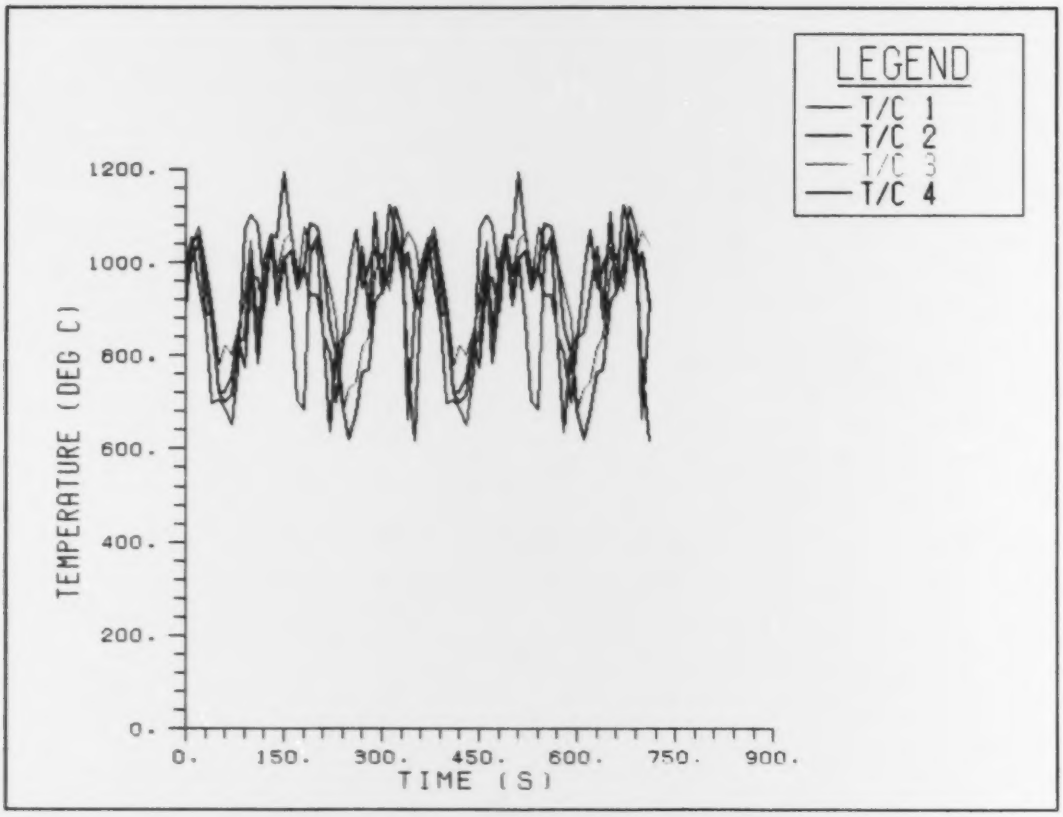


FIGURE 25

MEASUREMENTS OF FLAME TEMPERATURES